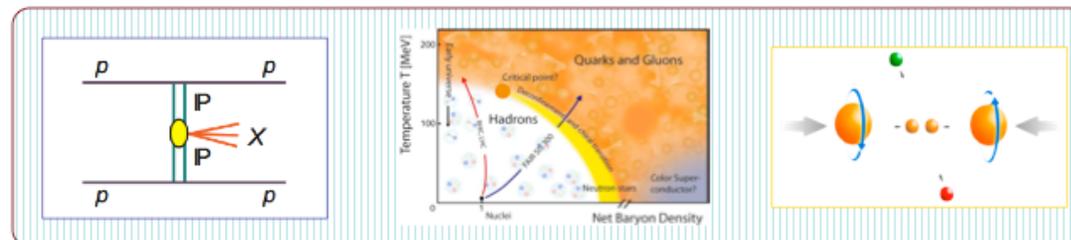


# STAR Experiment at RHIC

Nu Xu  
for the STAR Collaboration

Nuclear Science Division  
Lawrence Berkeley National Laboratory



## **STAR operations performance and plans**

- (1) Operational efficiency in Run 10
- (2) Detector performance improvements from recent and ongoing upgrades (incl. capital equip.)
- (3) Progress on new decadal plan
- (4) Comments on collaboration input to RHIC resource management decisions



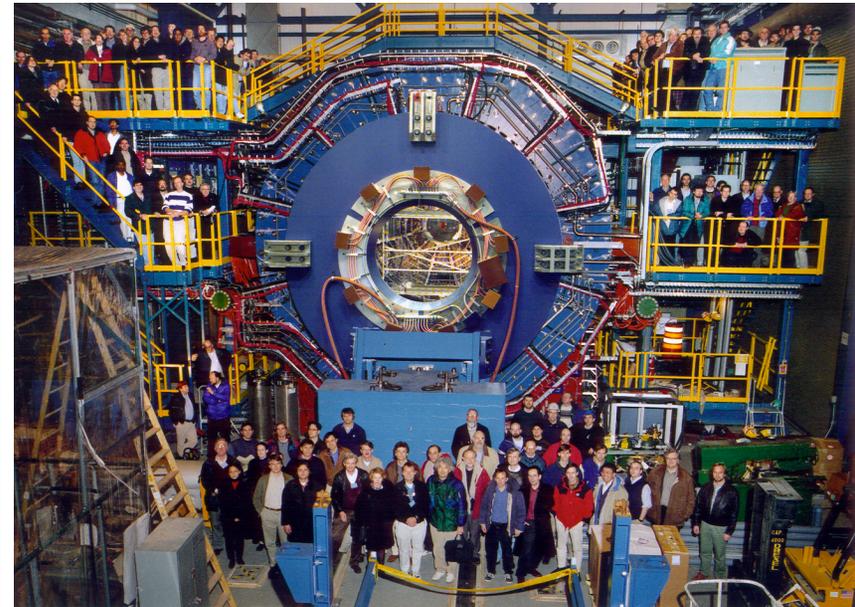
# STAR Collaboration Membership

**U.S. Labs:** Argonne, Lawrence Berkeley, Brookhaven  
**U.S. Universities:** UC Berkeley, UC Davis, UCLA, *Carnegie Mellon*, Creighton, CCNY, Indiana, UIC, Kent State, MSU, Ohio State, Penn State, Purdue, Rice, Texas A&M, UT Austin, Washington, Wayne State, Valparaiso, Yale, MIT, Kentucky, Old Dominion U  
**Brazil:** Universidade de Sao Paulo, Universidade Estadual de Campinas  
**China:** IHEP, IOPP, USTC, Tsinghua U, SINAP, IMP, ShanDong U  
**Croatia:** Zagreb U  
**Czech Republic:** Institute of Nuclear Physics, Czech Technical U  
**England:** U of Birmingham  
**France:** *Institut de Recherches Subatomiques Strasbourg*, SUBATECH  
**Germany:** Max Planck Institute, Frankfurt (BES)  
**India:** IOP, Bhubaneswar, Jammu U, IIT-Mumbai, Panjab U, Rajasthan U, VECC  
**Netherlands:** *NIKHEF*  
**Poland:** Warsaw U of Technology  
**Russia:** MEPHI, LPP/LHE JINR – Dubna, IHEP – Protvino, ITEP  
**South Korea:** Pusan National U, KISTI

= **Six new institutes joined in 08-09**

= **New institutes** have applied for membership:

- (1) HIT, China: two-particle correlation
- (2) GSI, Germany: Hypernuclear production



*13 countries*  
*51 active institutes*  
*~ 600 scientists and engineers*

## **Research topics at the QCD Lab:**

- properties of sQGP & QCD critical point
- proton spin structure
- gluonic matter: CGC, DPE

List of degree recipients: 129 PhD and 21 other degrees awarded on **STAR** research to students at 34 institutions

**Jammu University**  
 2009 Sunil Manohar Dogra, PhD  
 2009 Neeraj Gupta, PhD

**Max-Planck-Institut**  
 2005 Frank Simon, PhD  
 2004 Joern Putschke, PhD  
 2003 Maierbeck Peter, Dipl.

2002 Maierbeck Peter, Dipl.  
 2000 H. ...  
 2000 T. ...  
 1998 F. ...  
 1997 M. ...  
 1997 X. ...

**MSU**  
 2002 M. ...

**Ohio**  
 2009 Z. ...  
 2004 S. ...  
 2004 M. ...  
 2003 F. ...  
 2002 F. ...

**Panjab**  
 2008, ...

**Purd**  
 2008 T. ...  
 2007 J. ...  
 2006 L. ...  
 2003 T. ...  
 2002 A. ...

**Rice University**  
 2010 Jianhang Zhou, PhD  
 2006 Jianhang Zhou, MS  
 2001 Martin DeMello, MS

**USTC China**  
 2009 Yichun Xu, PhD  
 2009 Zebo Tang, PhD  
 2007 Haidong Liu, PhD  
 2007 Yifei Zhang, PhD  
 2005 Xin Dong, PhD  
 2004 Shengli Huang, PhD  
 2004 Lijuan Ruan, PhD

**IOP, Bhubaneswar**  
 2010 Sadhana Dash, PhD  
 2007 R. Sahoo, PhD

**SUBATECH**  
 2010 Artemios Geromitsos, PhD  
 2005 Magali Estienne, PhD  
 2004 Gael Renault, PhD  
 2003 Ludovic Gaudichet, PhD  
 2002 Javier Castillo, PhD  
 2000 Fabrice Retiere, PhD  
 2000 Walter Pinganaud, PhD

**University of Bern**  
 2005 Mark Heinz, PhD

**University of Birmingham**  
 2009 Thomas Burton, Ph.D  
 2008 Anthony Timmins, PhD  
 2008 Leon Gaillard, PhD  
 2005 John Adams, PhD

**Wayne State University**  
 2006 Ahmed Hamed, PhD  
 2005 Ying Guo, PhD  
 2005 Alexander Stolpovsky, PhD

**Nucl. Physics Inst., Prague**  
 2008 P. Jakl, BS  
 2006 Jan Kapitan, MS

129 Ph.D degrees  
 21 other degrees

(Since last review: 14)

**STAR continues to do an excellent job of educating the next generation of physicists!**

2008 Fei Du, PhD  
 2007 Betty Abelev, PhD  
 2006 Sevil Salur, PhD  
 2004 Jon Gans, PhD  
 2003 Haibin Zhang, PhD  
 2003 Michael Miller, PhD  
 2002 Matthew Horsley, PhD  
 2001 Manuel Calderon, PhD

**IUCF**  
 2008 Weihong He, PhD

**SINAP**  
 2010 Jian Tian, Ph.D  
 2010 Fu Jin, Ph.D  
 2009 Xinghua Shi, PhD  
 2009 Song Zhang, PhD

2003 Sarah Parks, MS  
 1999 Jie Lin, MS  
 1998 Quinn Jones, MS  
 1996 John Meier, MS  
 1995 Jeffrey Gross, MS

**Texas A&M**  
 2008 Michael Daugherty, PhD  
 2006 Thomas Henry, PhD

**NIKHEF/Utrecht**  
 2008 Federica Benedosso, PhD  
 2008 Martijn Russcher, PhD  
 2007 Yuting Bai, PhD  
 2007 Oleksandr Grebenyuk, PhD

2005 Gang Wang, PhD  
 2003 Ben Norman, PhD  
 2002 Wensheng Deng, PhD  
 2002 Aihong Tang, PhD

**LBNL**  
 2008 Xiangming Sun, PhD  
 2007 Sarah Blyth, PhD  
 2007 Mark Horner, PhD  
 2003 Vladimir Morozov, PhD

**LPP, JINR**  
 2006 Alexei Zubanov, BS

**MEPhI, Moscow**  
 2007 Sergei Timoshenko, PhD  
**MIT**

Blue = awarded 2009-2010



# STAR Publications

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Total # of refereed publications: 124 !

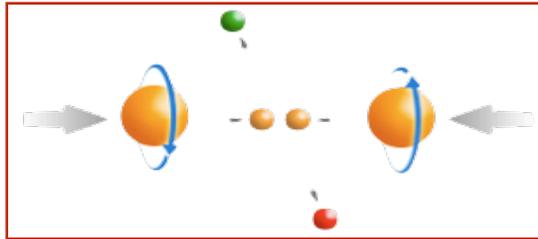
- *Phys. Rev. Lett*: 49, *Phys. Rev*: 50, **Science: 1** ...

2009-2010: Total # of publications since last review: 23

- *Phys. Rev. Lett*: 3, *Phys. Rev*: 12, *PLB*: 1; *Science*: 1  
and 6 manuscripts are in referee process.

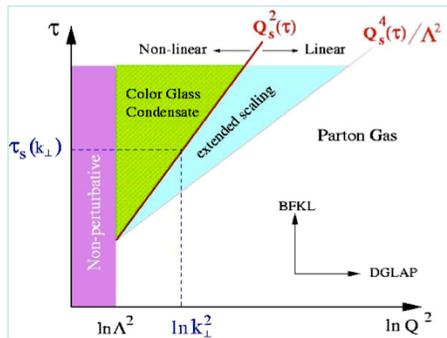
**STAR is productive!**

# STAR Physics Focus



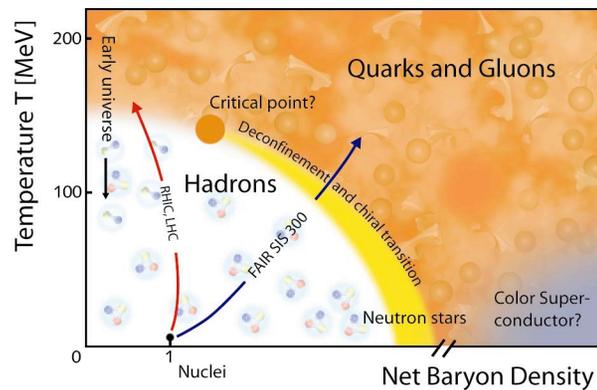
## Polarized $p+p$ program

- Study *proton intrinsic properties*



## Forward program

- Study low-x properties, search for **CGC**
- Study elastic (inelastic) processes (pp2pp)
- Investigate *gluonic exchanges*



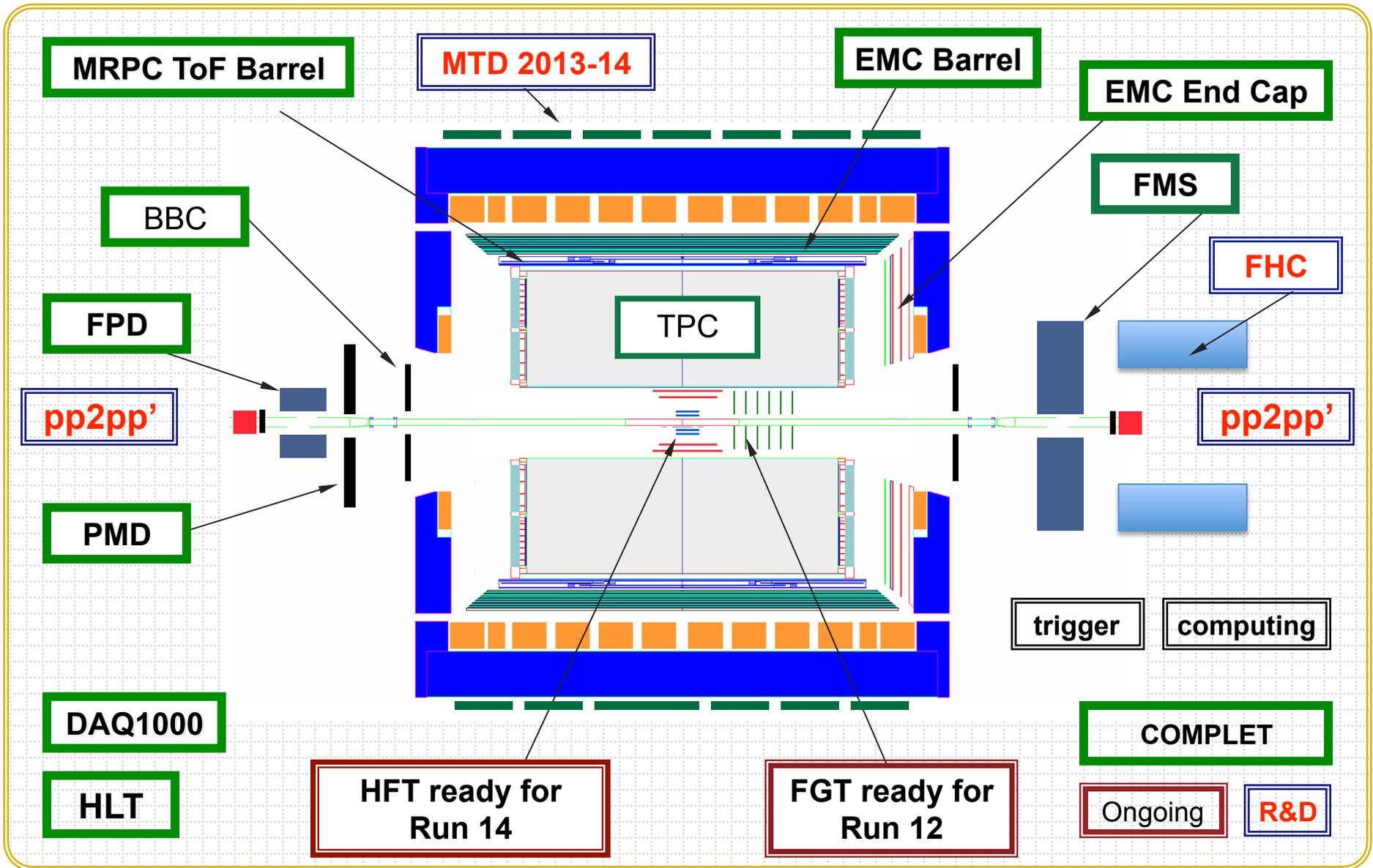
## 1) At 200 GeV top energy

- Study *medium properties, EoS*
- pQCD in hot and dense medium

## 2) RHIC beam energy scan

- Search for the **QCD critical point**
- Chiral symmetry restoration

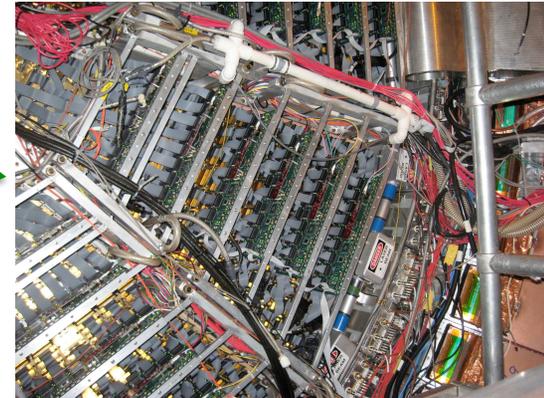
# STAR Experiment



- (1) Results from Run 10
- (2) Detector performance improvements from recent and ongoing upgrades (including capital equipment)

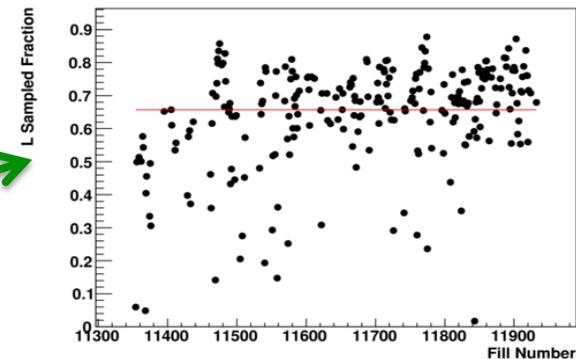
# Changes for Run 10

- 1) Completed installation of MRPC TOF
  - All 120 trays installed prior to run 10

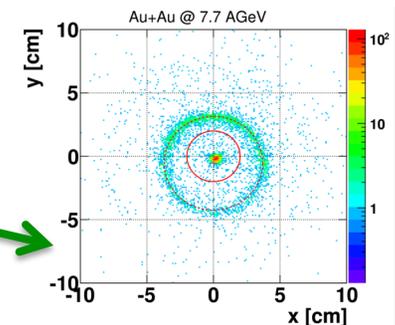


- 2) New Barrel Shower Maximum readout
  - Installed prior to run 10
  - Run at 500 Hz at dead-time ~ 17%

- 3) Operational optimization
  - Laser calibration events taken in parallel with physics event (TCU board)
  - Pedestals taken once per day
  - No need to reconfigure trigger
  - 15% increase in luminosity sampling efficiency → **65.7%!**  
(on top of the factor of two increase from DAQ1k)

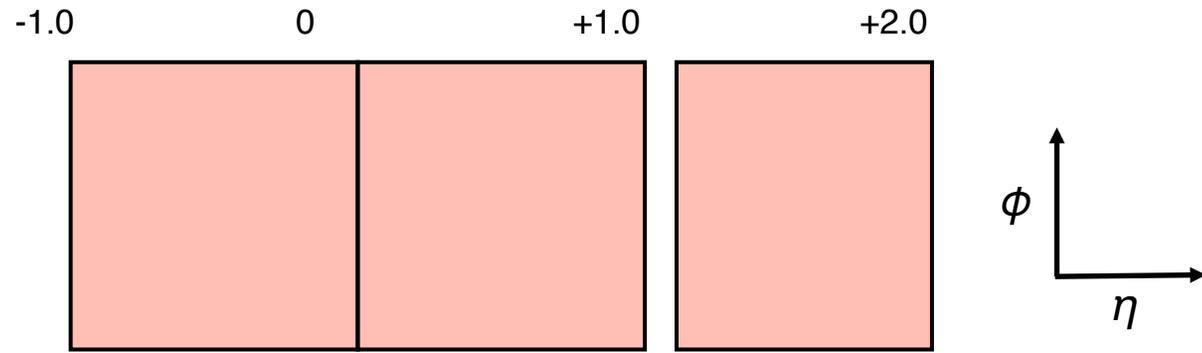


- 4) Extensively used High Level Trigger
  - QA during Beam Energy Scan
  - Online event selection



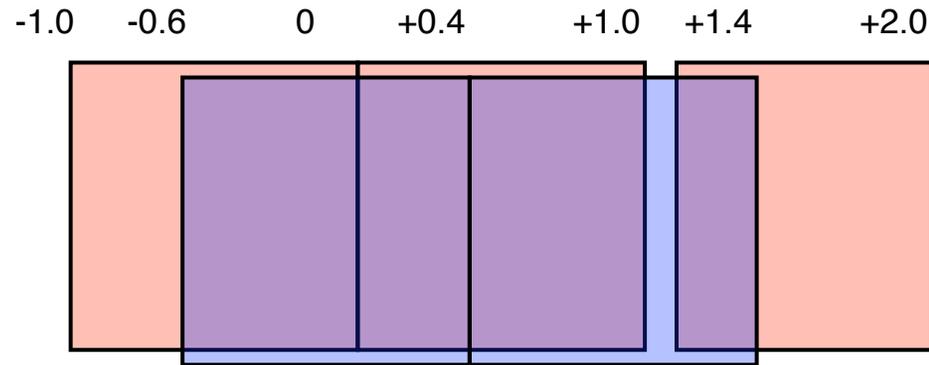
# Evolution of Jet Triggers

Through Run 8:



Three 1x1 patches, non-overlapping in  $\eta$

Beginning Run 9:



To aid visualization, two of the patches were slightly offset in  $\phi$

Five overlapping patches in  $\eta$  to:

(a) enhance trigger efficiency; (b) reduce trigger bias

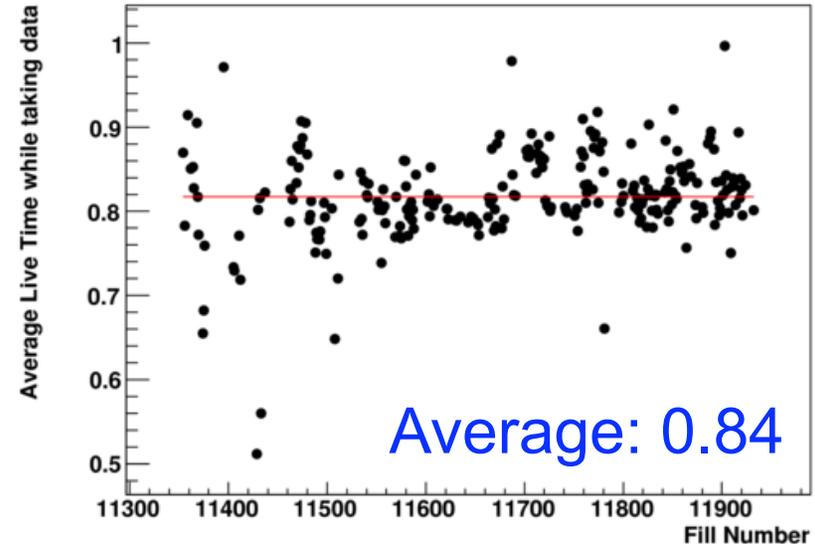
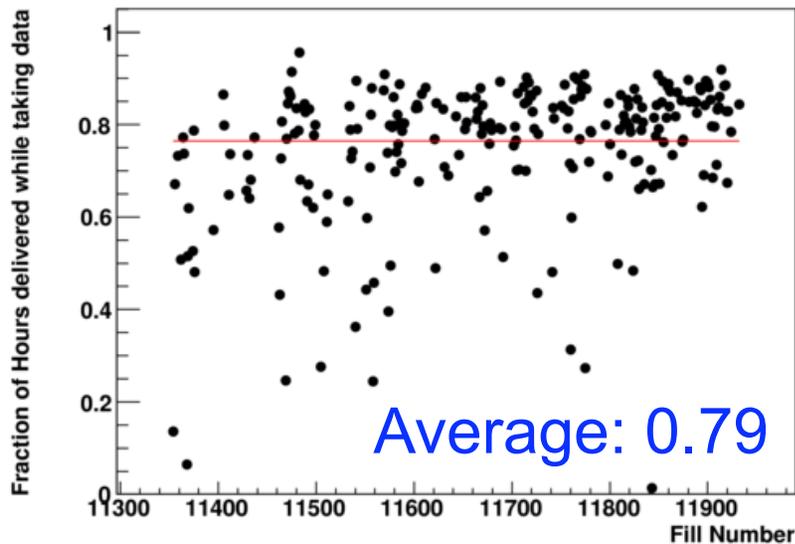
Future using TCU boards and DSM boards



# Efficiency at Au+Au 200 GeV

## Typical DAQ rate 500 Hz

□ Fraction of hours delivered while taking data      — Average live time while taking data



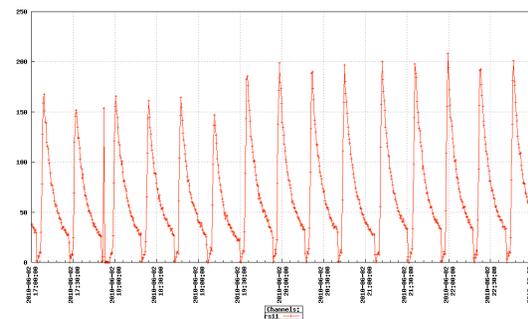
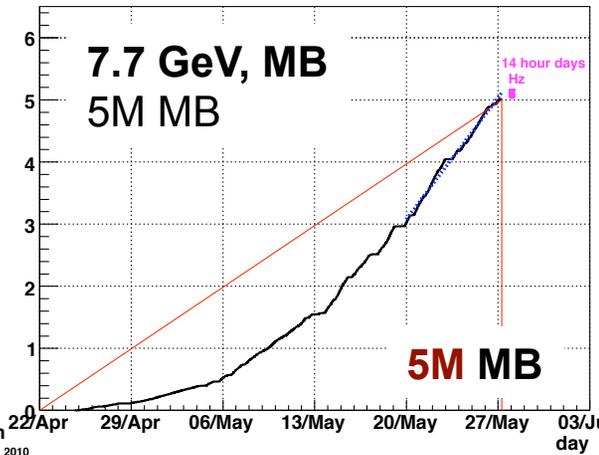
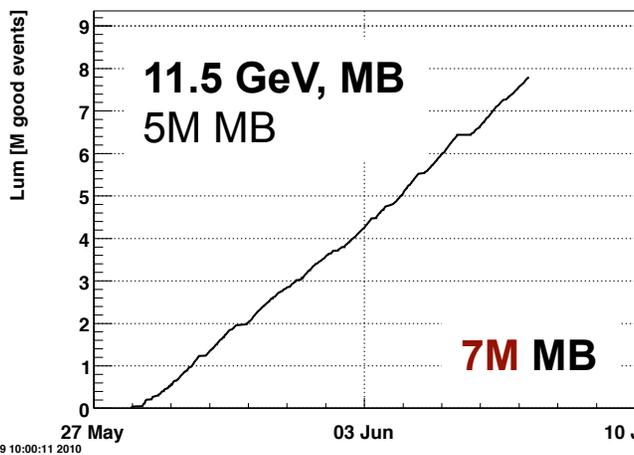
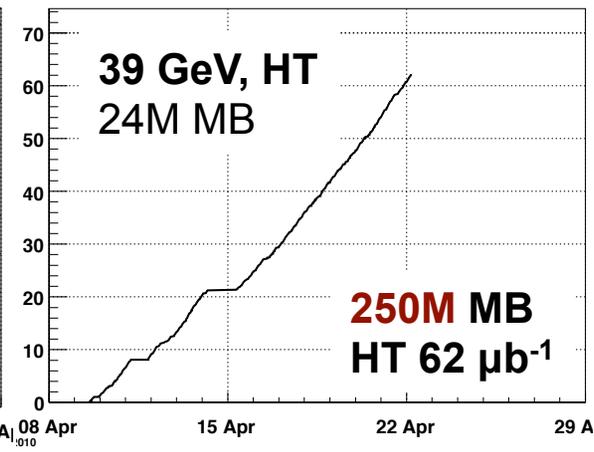
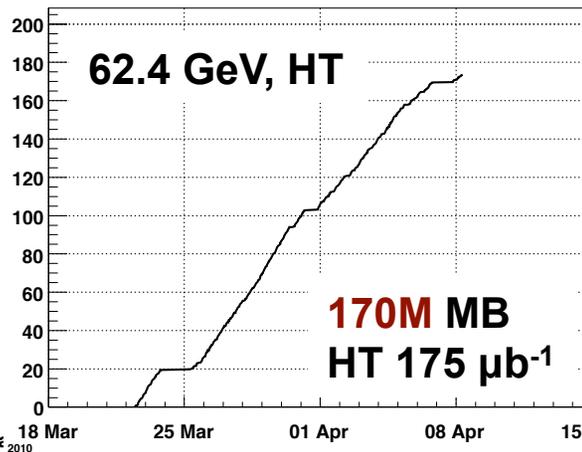
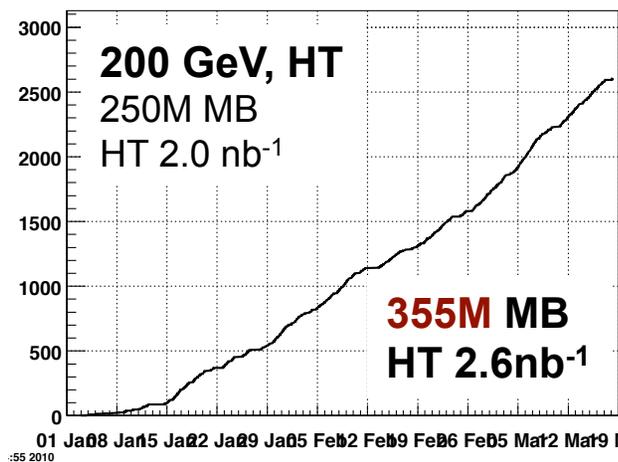
Run 10: **65.7% at 500Hz!**

Run 7: **20.2% at 30-50Hz**



# Run 10: 200, 62.4, 39, 11.5 7.7 GeV

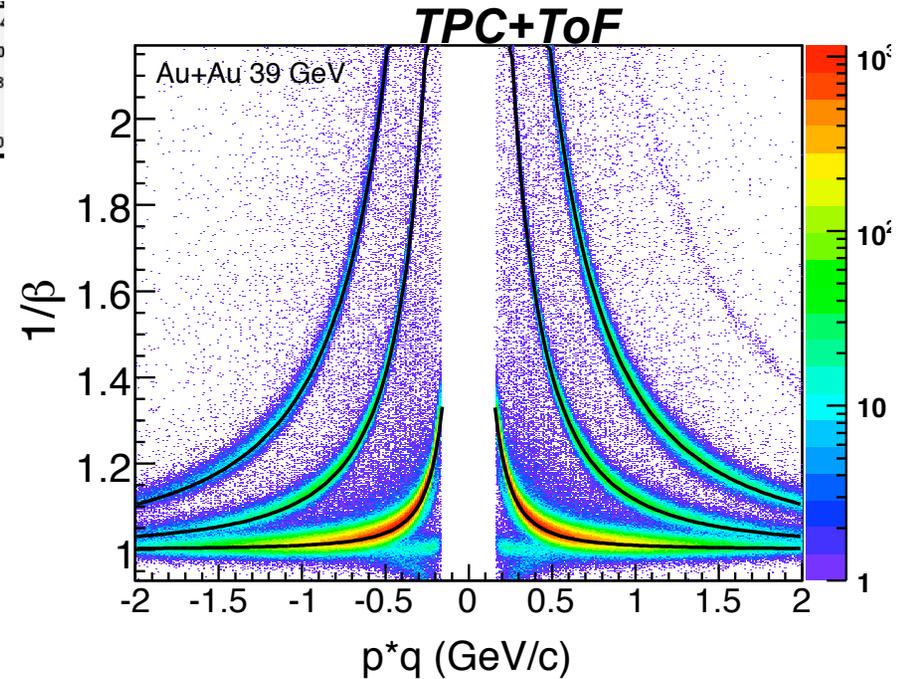
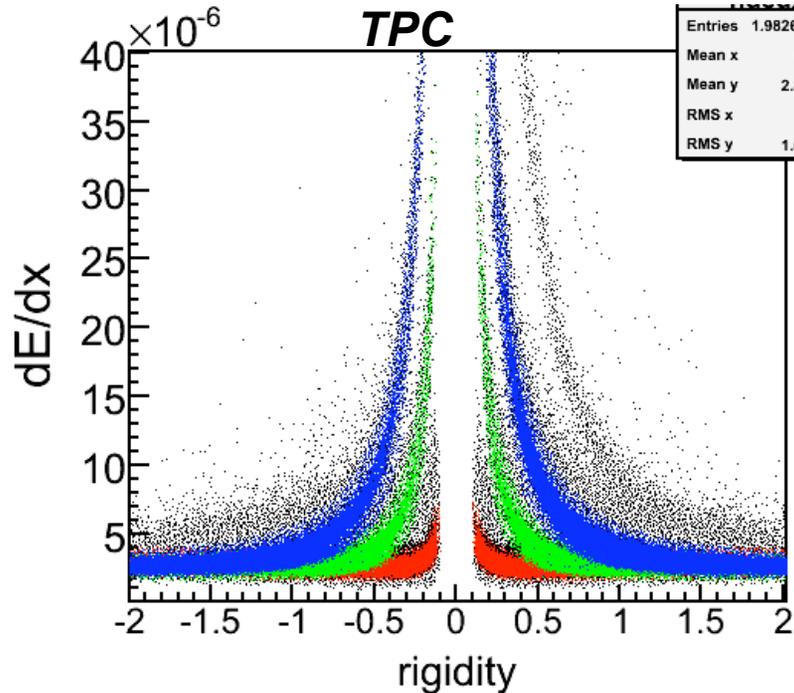
A great success, many thanks to CA-D!



- 1) Successful run, all goals were reached or exceeded
- 2) Excellent collaboration between STAR and CA-D during the run

# Run 10 Performance

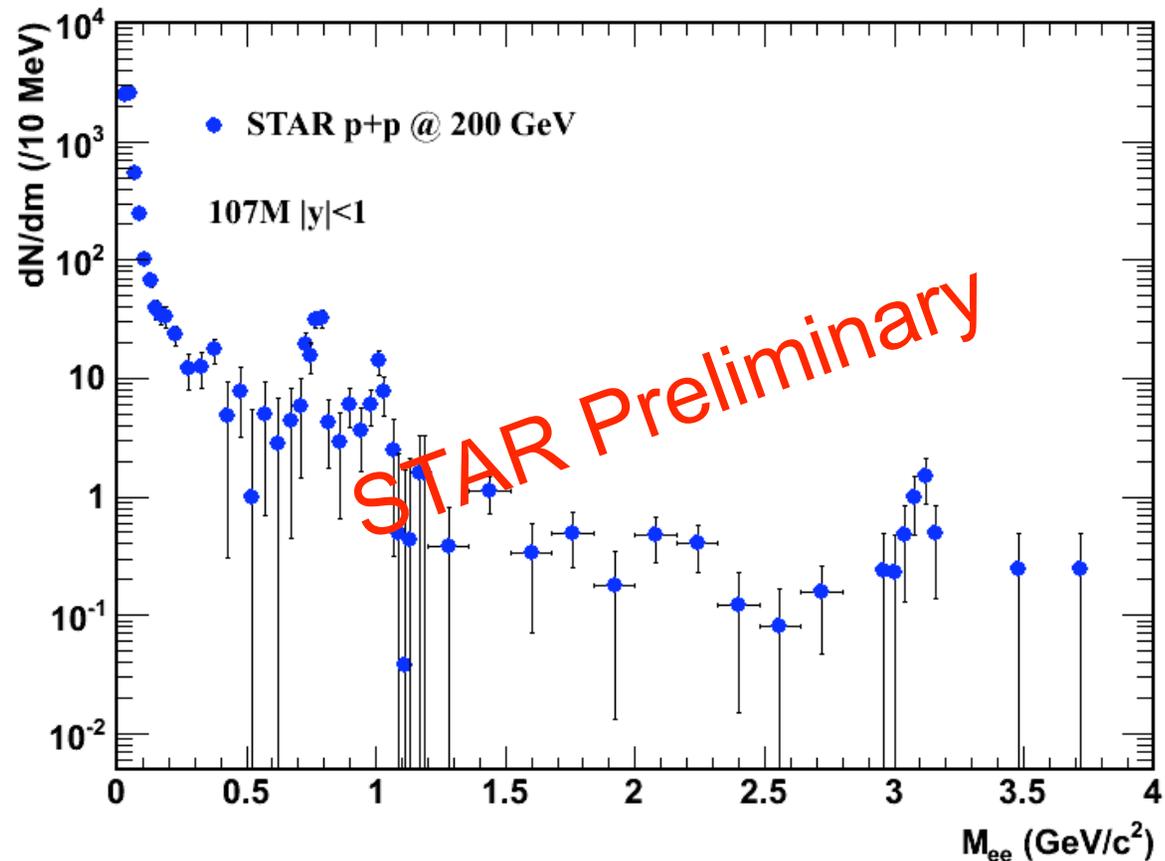
$\sqrt{s_{NN}} = 39 \text{ GeV Au + Au Collisions}$



Beam Energy	Timing Resolution	Remarks
200 (GeV)	85 (ps)	At 39 GeV, using a new calibration scheme without information of start time from VPD, 87 ps of timing resolution has been achieved.
62.4 (GeV)	90 (ps)	
39 (GeV)	85 (ps)	
11.5 & 7.7 (GeV)	~ 80 (ps)	



# Di-lepton Program at STAR



- 1) Run 9: 200 GeV p+p collisions, 75% TOF installed.
- 2) STAR will do the di-electron analysis for Au+Au collisions data from Run 10 with 100% TOF.
- 3) **Run 11 request:** 150M events from 27 GeV Au+Au collisions.



## (3) STAR Decadal Plan Activities

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**Membership:** Helen Caines, Hank Crawford, **Jamie Dunlop** (chair of heavy-ion task force), Olga Evdokimov, **Carl Gagliardi** (chair), Declan Keane, Thorston Kollegger, Bedanga Mohanty, Ernst Sichtermann, **Bernd Surrow** (chair of spin task force), Thomas Ullrich, **Flemming Videbaek** (chair of upgrades), Wei Xie, Nu Xu, Zhangbu Xu

**Meetings:** Every Wednesday. Discussed at past two collaboration meetings  
Collaboration wide meeting: Early Sept. at Chicago

### Issues will be discussed:

Science: **(i) Thermalization in sQGP?**

- parton energy loss, heavy quarkonia, di-electron.

**(ii) What is the QCD phase structure?**

- QCD phase boundary and critical point, glueball.

**(iii) What is the beginning of the beginning?**

- initial wave-function of the cold nucleus, proton helicity structure.

- Trigger for the next 10 years (enhance rare probe capabilities)
- Additional detectors at the forward rapidity (pA, ep, eA)
- Maintain and upgrade the existing detectors (e.g. replace or new TPC chambers)
- New members for the collaboration

“**For Scientific Discovery:** via Evolution, not revolution. Community. Cost effective.”

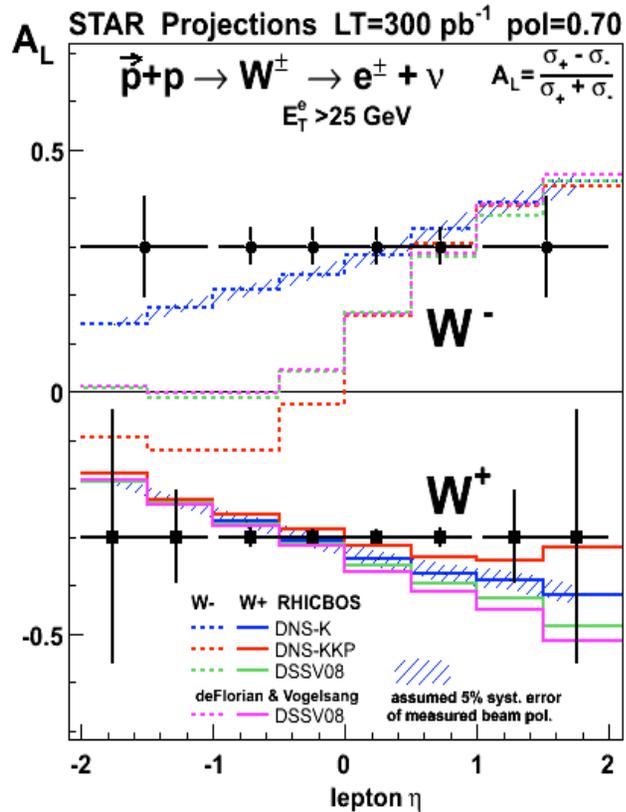
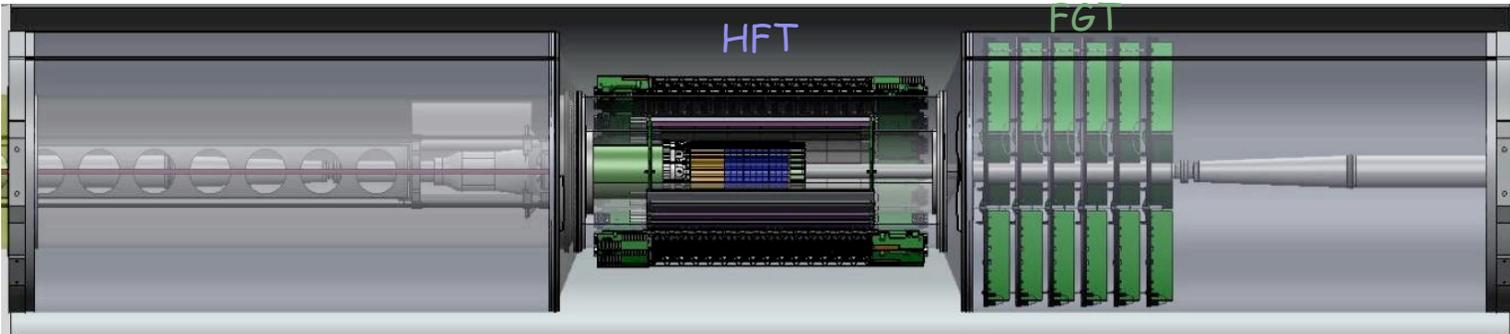


# STAR Upgrade Timeline\*

Upgrade	Completion	Key Physics Measurements
FMS	Completed 2008	(a) Trans. Asymmetry at forward-y (b) CGC
TPC DAQ1000	Completed 2009	Minimal dead time, large data set
MRPC TOF	Completed 2010	Fast PID in full azimuthal acceptance
Forward GEM Tracker	Summer 2011 Ready for Run 12	Forward-y $W^\pm$ for flavor separated quark polarization
Heavy Flavor Tracker	Summer 2013 Ready for Run 14	(a) Precision hadronic ID for charm and Bottom hadrons (b) Charm and Bottom hadron energy loss and flow
Muon Telescope Detector	Summer 2013 Ready for Run 14	(a) High $p_T$ muon trigger (b) Quarkonia states
pp2pp'	Summer 2014 Ready for Run 15	

\*Upgrades - Funding driven schedules

# Forward GEM Tracker

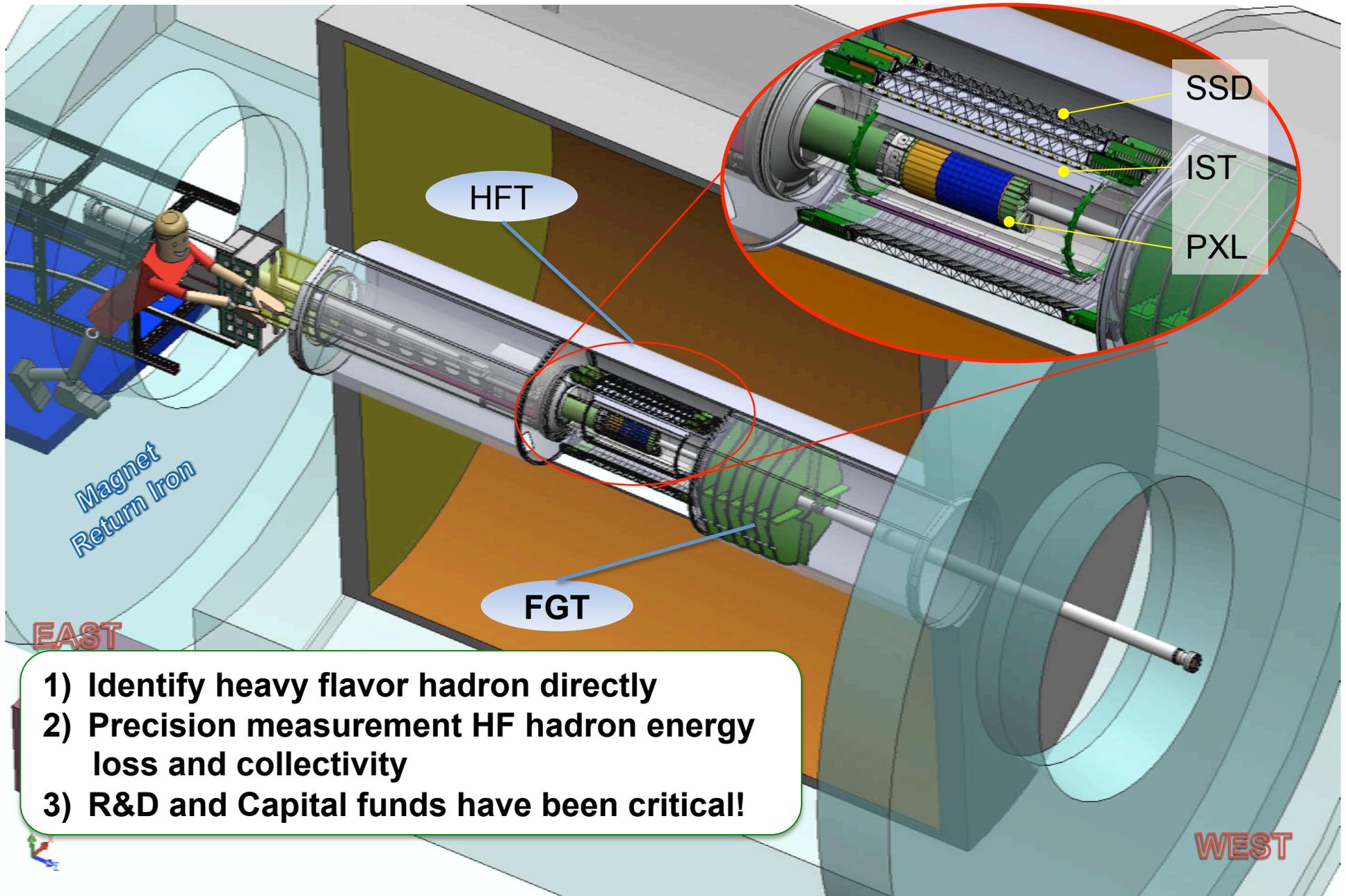


- 1) FGT: RHIC MIE project
- 2) Six light-weight triple-GEM disks
- 3) New mechanical support structure
- 4) Planned installation: Summer 2011

- 1) Full charge-sign discrimination at high- $p_T$
- 2) Design polarization performance of 70% to collect at least  $300 \text{ pb}^{-1}$

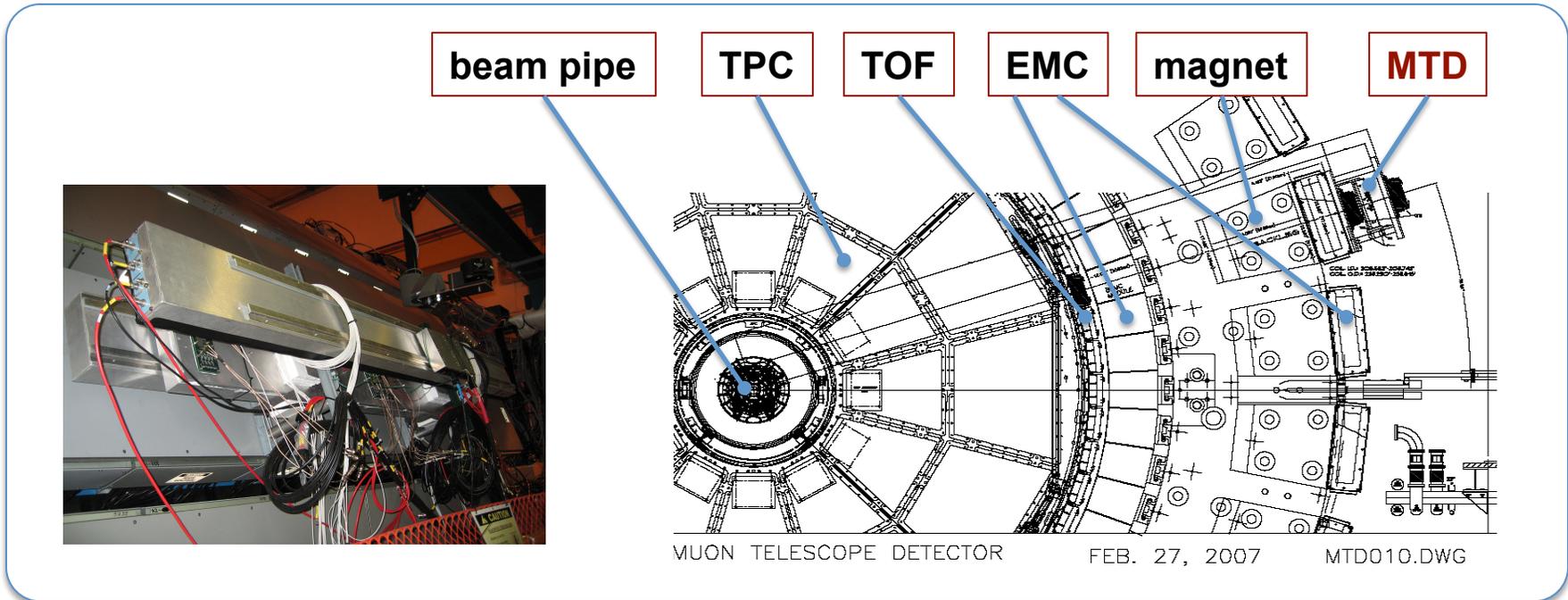


# Heavy Flavor Tracker at STAR



- 1) Identify heavy flavor hadron directly
- 2) Precision measurement HF hadron energy loss and collectivity
- 3) R&D and Capital funds have been critical!

# STAR: Muon Telescope Detector

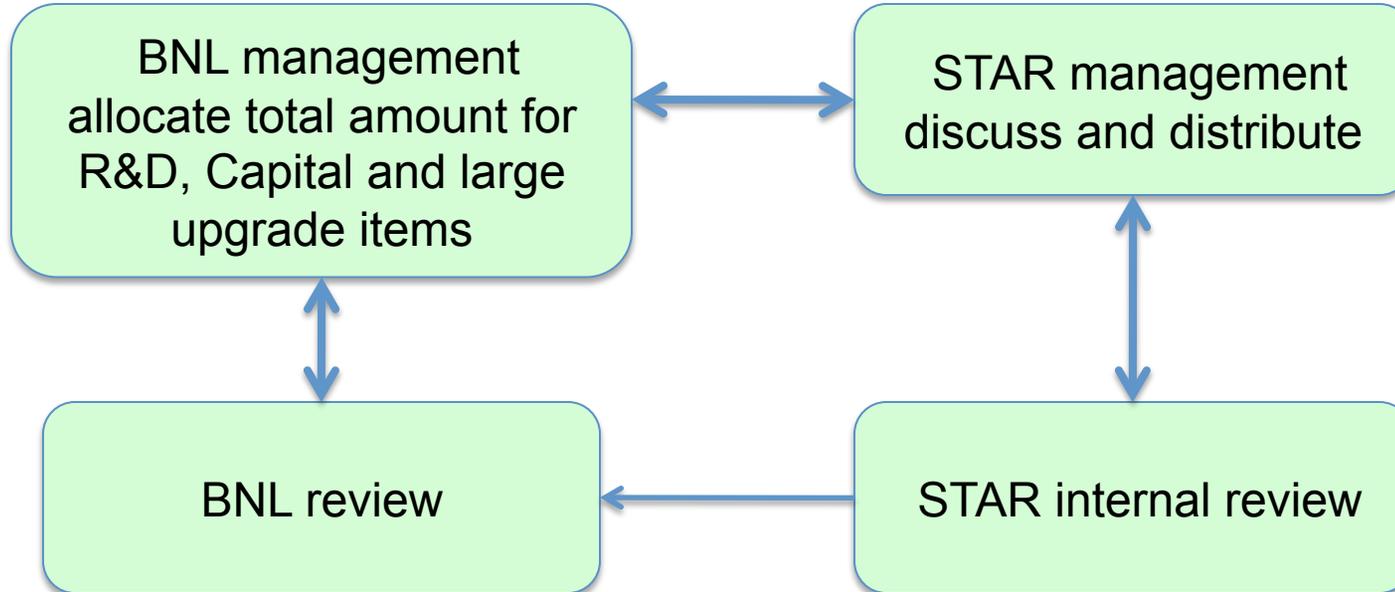


## Muon Telescope Detector (MTD) at STAR:

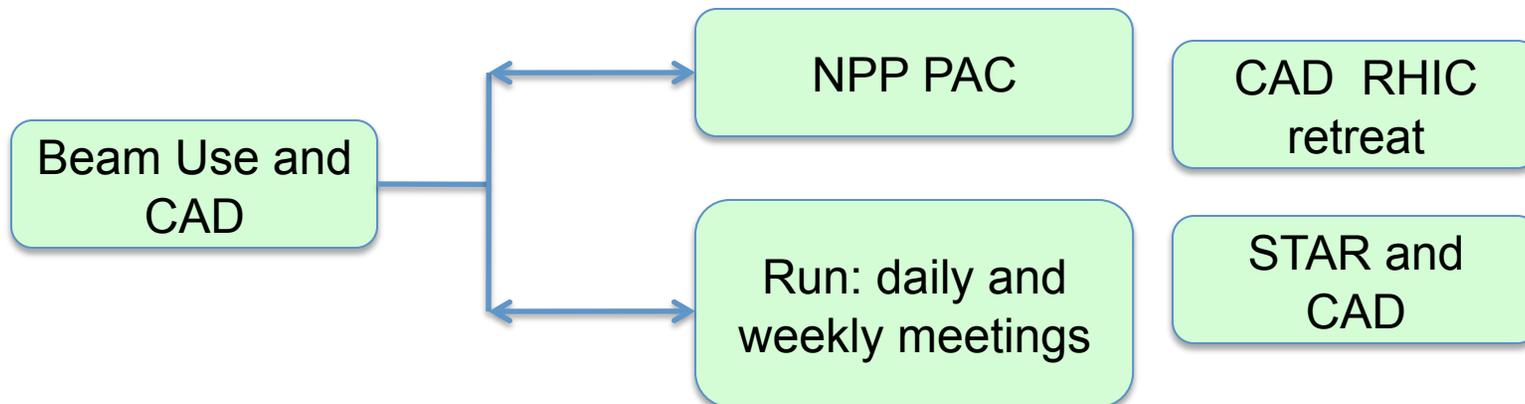
- 1) MRPC technology;  $\mu_{\epsilon} \sim 45\%$ ; cover  $\sim 60\%$  azimuthally and  $|y| < 0.25$
- 2) TPC+TOF+MTD: muon/hadron enhancement factor  $\sim 10^{2-3}$
- 3) For high  $p_T$  muon trigger, heavy quarkonia, light vector mesons,  $B \rightarrow J/\Psi + X$
- 4) China-India-STAR collaboration: a proposal sub. to BNL 02/2010.

(4) Comments on collaboration input  
to RHIC  
resource management decisions

### (1) Funding and Upgrades



### (2) Collider and Experiment



## (1) BNL:

**Excellent CA-D & exciting scientific program**

## (2) STAR program:

- Heavy Flavor: thermalization
- Beam Energy Scan: critical point & QCD phase structure
- Spin: proton helicity structure
- pp2pp and small-x: gluon
- eRHIC: discussions have started at STAR
  
- Upgrades: FGT (2011), HFT (2013), MTD (2013-14),  
Compact EMCal, FHC, ...